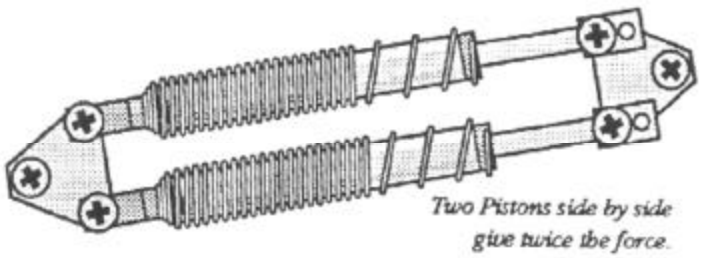
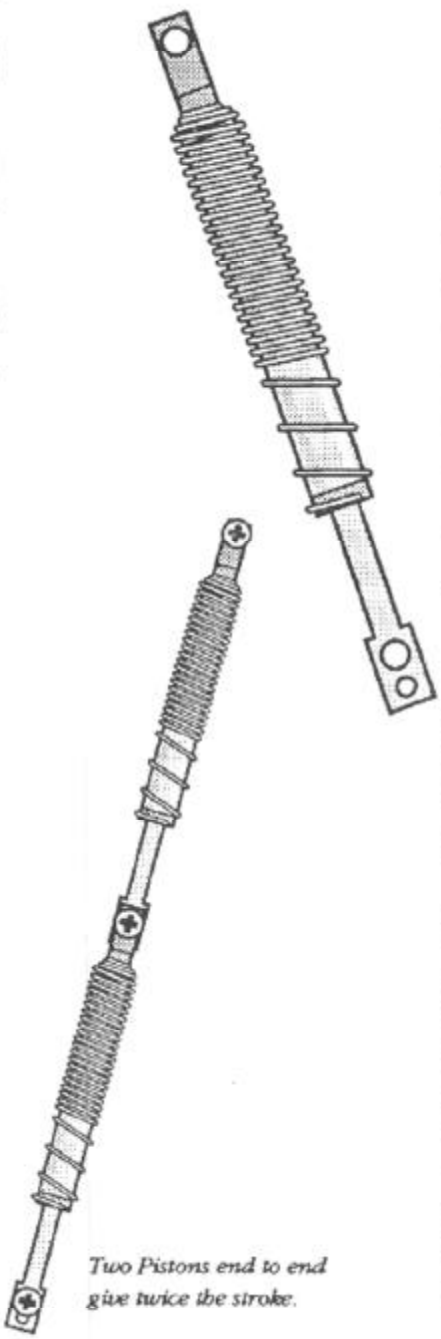
ELECTRIC PISTON™



Two Pistons side by side give twice the force.

3-137 Elec Piston Deluxe 5-Pack

Includes: Five Electric Pistons, one high-current P100 flat pack battery, two connecting wires and complete instructions.



Two Pistons end to end give twice the stroke.

Instructions

Welcome to the Electric Piston - a unique, all-electric linear actuator mechanism that shortens in length with great strength and speed. The secret to its operation lies in a remarkable Shape Memory Alloy (SMA) inside.

When carrying an electric current, the SMA spring heats and shortens in length. It shortens by 19 millimeters (0.75") and can lift up to 450 grams (1 pound) against gravity, yet the Electric Piston itself weighs only 10 grams!

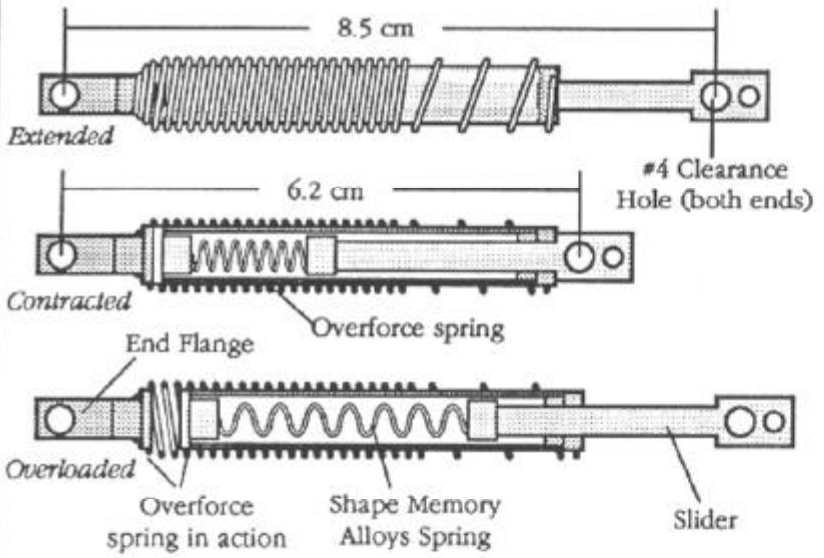
These instructions show proven ways of activating the Electric Piston and using it to generate motion. The Electric Piston opens the door to a whole new way of creating action from electricity. Use the projects shown here as starting points to develop your own amazing new applications.

Shape Memory Alloys

The group of metals known as Shape Memory Alloys (SMA) can assume radically different forms or "phases" at distinct temperatures. SMAs can be formed from a wide range of elements, but nitinol, the most widely used alloy, consists of nearly equal amounts of nickel and titanium. At the metal's "low" temperature it can be stretched easily or deformed by a small force.

But when raised to the "high" temperature (by an external heater or by carrying an electric current) the metal changes to a much harder form that returns to the "unstretched" shape, and exerts a usable amount of force. The ratio of its component elements determines the activation temperature of an SMA, and it is therefore set during the initial casting of the alloy.

SMAs most commonly come in the form of wires in a wide range of diameters. Researchers have also made SMA rods, ribbons, sheets, and tubes, but they are much less common due to their expense and their difficulty to manufacture. However, in wire form, SMAs can be easily formed and trained into a wide range of springs, coils and other shapes. Once trained they can be cooled, deformed and will recover their shape when heated. Springs can be wound in a wide range of sizes, then can be stretched or compressed when cool, and will recover their shape when heated. If not overstreched and not overheated, properly made SMA springs



PHYSICAL	
Length, relaxed:	100 mm
Length, contracted:	76 mm
Maximum diameter:	9 mm
Net stroke (no load):	23 mm
Net stroke (450 gram load):	19 mm
Mass:	10 grams
Operating force (on contraction):	450 grams (1.0 lb.)
Overload force:	680 grams
Reset force (to pull slider out):	250 grams
ELECTRICAL	
Total electrical resistance:	0.2 ohm
Maximum current:	5.0 amp
Minimum current:	2.0 amp
Typical current:	4.0 amp
Time to actuate at 4.0 A in 21°C still air:	
Time to start contracting:	2.5 sec
Time to 90 percent complete:	6.0 sec
Time to reset after 10 minutes "on":	
Time to start relaxing:	3.0 sec
Time to 90 percent complete:	7.0 sec
Typical cycle rate:	1–2 cycles per minute
THERMAL	
Contraction finish temperature (Af):	90 °C
Relaxation finish temperature (Mf):	65 °C
Self-actuating temp. (by external heating):	74 °C

Figure 1 Electric Piston Parts
Note how the overforce spring extends to protect the SMA spring (inside the cylinder) from overstraining when in the overloaded condition.

can perform for many thousands of cycles with great reliability and repeatability.

For more on the history and uses of Shape Memory Alloys refer to the *Muscle Wires Project Book* and the other books and articles given in the References section.

Actuation Power

Because the Electric Piston activates by electric heating, the contraction time varies greatly with the applied current. The higher the current, the faster the heating, and the faster the contraction. Currents over 10 amps can actuate the Piston in less than one second. However, higher currents require extra caution to protect the Piston's SMA spring from damage due to overheating.

Temperatures over 300°C (600°F) can cause permanent damage to the SMA coil spring and cause it to "lose its memory". Also, current levels below 2 amps generally will not heat the SMA spring sufficiently for actuation.

Actuation Temperature

Typically, the data and currents given here apply to projects operating at "room temperature" conditions (around 21°C or 70°F). Since the SMA spring's heating and cooling rate depends on the surrounding temperature, cold conditions require a somewhat higher activation currents and can have faster overall cycle times.

Powering the Piston

Electric current for powering the Electric Piston can come from many sources. Some batteries, such as Polaroid's Polapulse P100, and rechargeable nickel-cadmium cells, can produce very high currents for

reasonable periods of time. Benchtop and other AC powered supplies can produce continuous high currents and provide good power sources for fixed projects. Project 4 in these instructions includes plans for a simple 5 amp power supply that uses AC power. Even car, motorcycle and marine batteries produce sufficient current for driving Electric Pistons.

Caution: Always use extreme care when working with high output batteries and circuits. Use proper eye protection and follow all appropriate safety and handling precautions.

PROJECT 1

Electric Piston & Battery Power Circuit

This project demonstrates the basics of powering an Electric Piston with a battery, and of using its strength to lift a weight against gravity.

Linear Action Parts List

1	each	Electric Piston
1	each	High Current Battery (Polapulse P100 or NiCd pack)
2	each	Wires, insulated, 22 AWG min.
1	each	Weight, 450 grams (1 lb fishing weight)
1	each	Paper clip or wire hook
1	each	Base (wood block)
1	each	Finishing Nail or #4 wood screw

Construction:

Strip the ends of the two connecting wires and attach them to the Electric Piston; wrap one through the small hole on the slider, and slip the other wire between the coils of the overforce spring by bending back the flange to hold the wire against the Piston (OK for a temporary connection).

Hammer the finishing nail part way into the wood base. Hang the Piston on the nail, and hang the weight from the Piston with the paper clip.

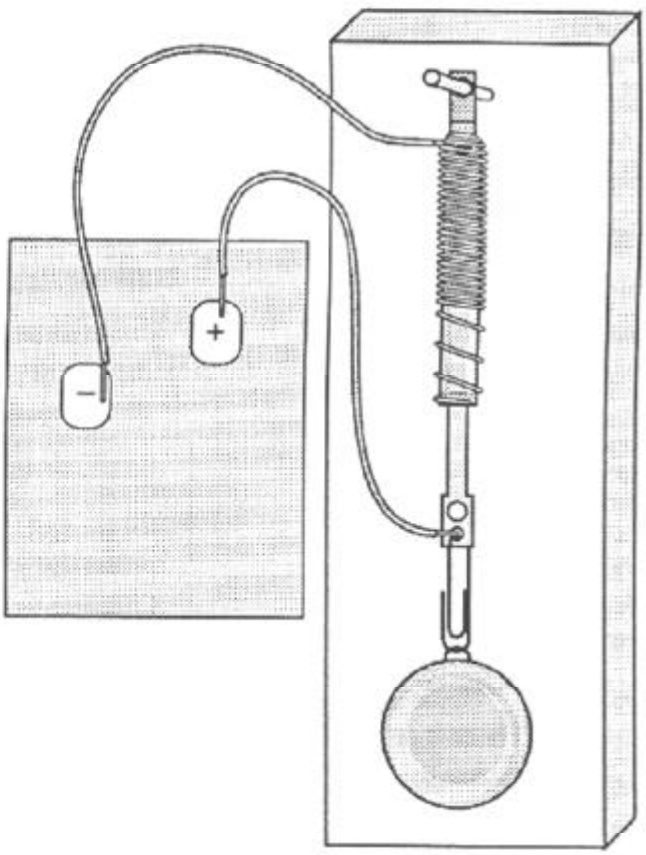


Figure 2 Project 1, Linear Action with Electric Piston
For stability, hold the wooden block in a clamp or table vice. Touch the wires from the Electric Piston to the battery *briefly* to prevent overheating.

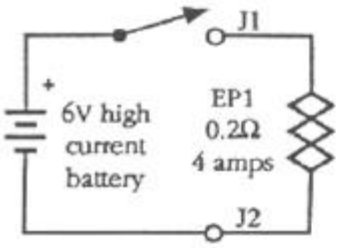


Figure 3 Basic Schematic
The "three diamonds" symbol at EP1 indicates the SMA coil inside the Electric Piston.

How It Works:

Touch the ends of the connecting wires to the battery, one to the "+" terminal, and the other to the "-" terminal (either wire can go to either terminal). Be prepared to remove the connection quickly once the Piston has contracted to protect it from overheating.

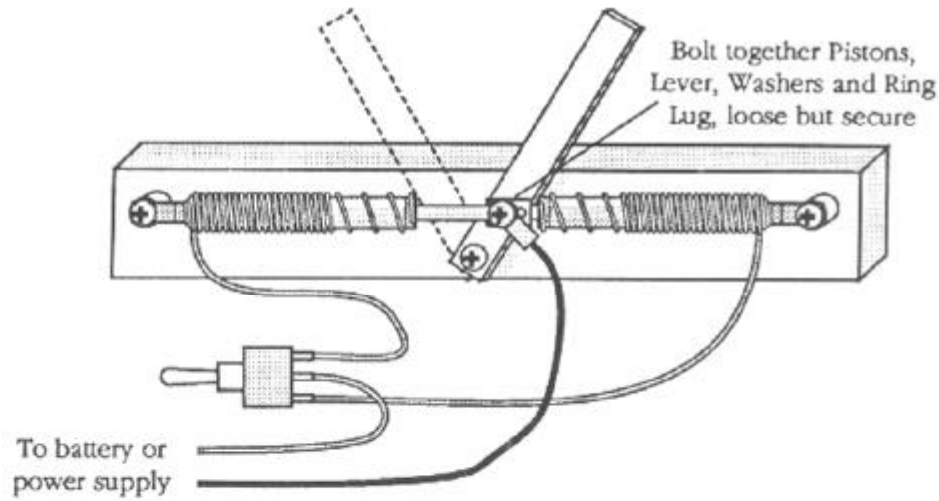
Variations:

Use this basic linear contraction to make a latch for a hidden door or panel, a pet door opener, an electric trunk release and many other devices.

Use more permanent construction to build devices that will hold together under repeated operation.

PROJECT 2

Opposing Pistons



Two Electric Pistons and a special double-throw (momentary-off-momentary) switch make a device that moves in two directions.

This arrangement requires a pause when one Piston has finished being powered before activating the opposing Piston. Under standard "room temperature" conditions, allow 30 seconds or so for the Piston to cool.

Double Piston Parts List

2	each	Electric Piston
1	each	High Current Battery (Polapulse P100 or NiCd pack)
1	each	Switch, 2 position, moment-off-moment (Mouser #10TC245)
1	each	Base, wood block, 20 x 2 x 2 cm
1	each	Lever, plastic sheet, 1 cm x 10 cm x 0.4 cm
1	each	Screw, #4-40 x 1/2"
1	each	Screw, #4-40 x 1"
2	each	Nut, #4-40, hex
2	each	Washer, #4, flat
1	each	Ring lug, #4 (Digikey #A1091)
2	each	#4 Standoff
		Wire, insulated, 22 AWG min.

Construction:

Build as shown, connecting the moving ends of the Piston and the common power wire with a screw, nut and a ring terminal crimped to the connecting wire.

Before mounting the outside ends, power one of the Pistons to make it contract fully, then pull on the other to extend it.

How It Works:

Press the momentary switch in one direction to power one Piston until it contracts. Turn power off and pause 30 seconds. Then power the opposing Piston to contract itand extend the other Piston, and move the lever arm. By carefully powering the Pistons, the lever can be positioned as desired.

PROJECT 3

Pin Puller & Digital Watch Timer

In this device an Electric Piston pulls a pin from a socket at a preset time, permitting the release of a parachute from a kite, or other similar actions.

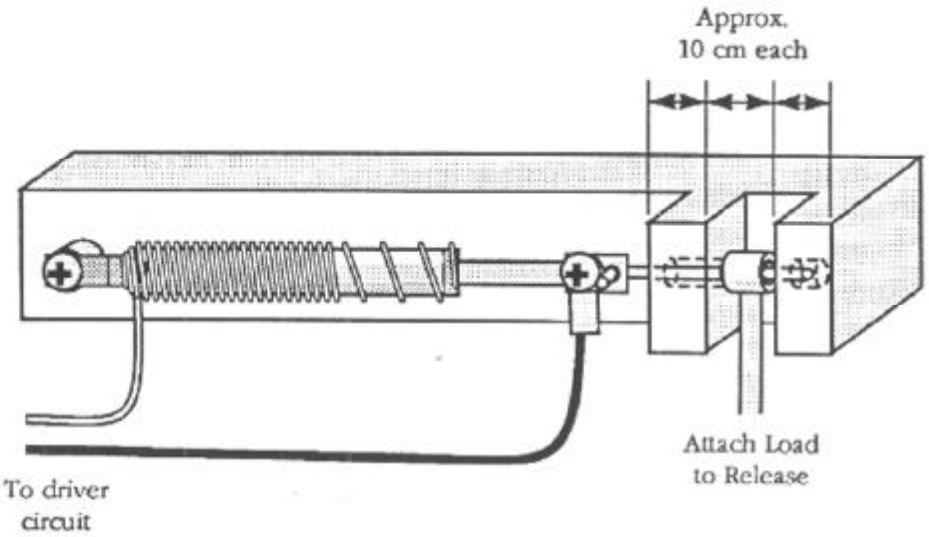


Figure 5 Project 3, Pin Puller Release Mechanism
This unique device uses the strong linear contraction of the Electric Piston to pull a pin and free a detained loop. Use it to release a parachute from a kite and for similar actions in model planes, boats, etc. Use the timer circuit for the timed opening of pet feeders, hidden panels, etc.

Construction:

The circuit uses an inexpensive digital watch with an alarm to activate the Electric Piston and pull the pin.

Fabricate the pin puller base from a block of wood or plastic as shown in Figure 5. Make the pin from a brass rod or bent nail and insert it into the hole. It must slide freely for best operation.

This circuit can be built using many common methods. Use perf board and soldering for durability. Locate the components on the perf board, and connect according to the schematic (Fig. 6).

The digital watch can be any common and inexpensive type (showroom and discount department stores are likely places to find them), but it must have an alarm.

Carefully open the back of the digital watch. To connect it to the driver circuit, locate and solder wires to two points: 1) the positive voltage side of the battery, and 2) the alarm output point. Most watches run on either 1.5 or 3 volts. With a volt meter, find a positive voltage point on the circuit board at or near the battery (or batteries). Use a thin hookup wire and just enough solder to attach to the positive voltage point (not directly to the watch battery).

The alarm buzzer should be a thin dull gold or silver disk inside the back cover. On the watch cir-

Pin Puller Parts List

1	each	Electric Piston
1	each	Base, wood or plastic, 14 x 2 x 2 cm (fabricated as shown)
1	each	Pin, brass rod, 1.5 mm dia x 3 cm long
1	each	Screw, #4-40 x 1/4"
1	each	Nut, #4-40, hex
1	each	Washer, #4, flat
1	each	Ring lug, #4 (Digi-Key #A1091)
1	each	Wood Screw, #4, 1"
1	each	Standoff, #4
		Wire, insulated, 22 AWG min.

Watch Timer
Parts List

1	W1	Digital Watch with Alarm (see text)
1	U1	IC, 4N25, Optoisolator (Digi-Key #4N25GI)
1	U1	Socket, 6 pin, DIP
1	R1	Res, 1K Ω, 1/4 W (Brn, Blk, Red, Gold)
1	R2	Res, 100K Ω, 1/4 W (Brn, Blk, Yel, Gold)
1	Q1	Trans., IRFZ30, MOSFET, PNP (Digi-Key #IRFZ30)
1	I1	LED, Red
1	B1	High Current Battery (Polapulse P100 or NiCd pack)
		Perf board
		Hookup wire

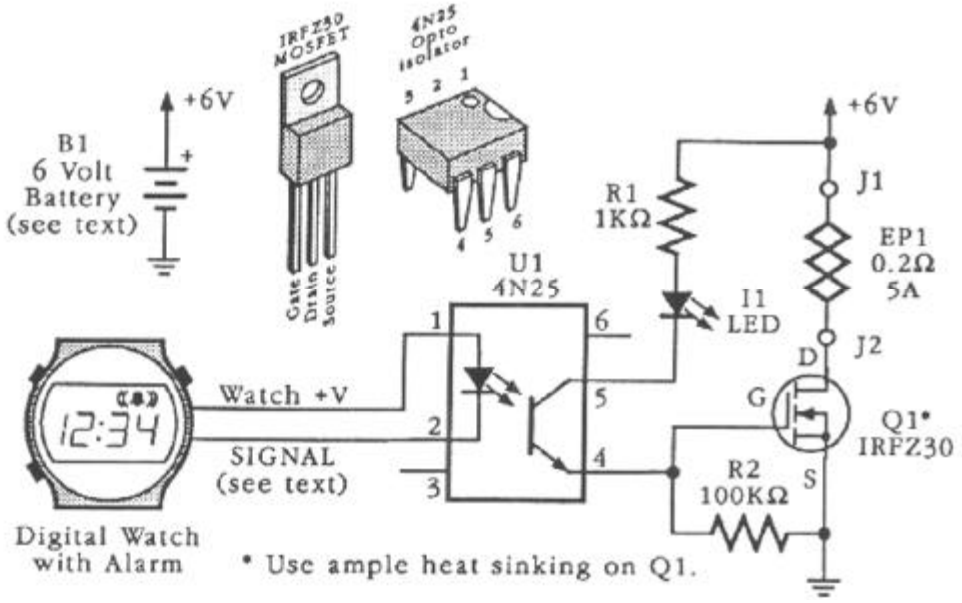


Figure 6 Schematic for Digital Watch Timer Circuit
This circuit connects the alarm output of a standard digital watch to an optoisolator (U1). When the alarm activates, it applies power to the Electric Piston, and pulls the pin.

cuit, look for a small spring or metal finger that touches the buzzer when the cover is in place. This is the alarm output. Solder another thin hookup wire to the output point.

Cut or file a notch in the back cover and replace it, passing the two wires through. With a volt meter, recheck the connections at the wires. With the alarm active it should have a varying signal, from 0 to 1.5 or 3 V, depending on the watch.

Finally, connect the wires from the watch to the circuit in Figure 6. Test the alarm to be sure that the red LED lights when it triggers. Finally, attach the circuit to the assembled pin puller mechanism and test the entire system.

How It Works:

When powered, the Piston pulls the latch pin and freeing the load. When power is removed the Piston relaxes and the pin can be reset.

The digital watch contains sophisticated electronics in a small, inexpensive package. The oscillating signal that normally powers the watch's buzzer provides a low signal to Pin 2 of U1, the optoisolator.

Inside U1, the signal lights an LED which shines on a photo transistor and permits power to flow from Pin 5 to Pin 4. This lights the red LED I1, and provides a positive voltage to the base of Q1. With the gate positive, power flows between its source and drain and through the Electric Piston.

Resistor R1 limits the current to LED I1, and R2 provides a bias to pull the base of Q1 to low and fully turn it off.

Variations:

Use this device for dropping a parachute from a kite or model plane, or for other kinds of remote releasing, and for timed locking or unlocking.

Use two timer circuits to operate the Dual Piston in Project 2, setting one timer to an "open" time and the second to a "close" time. Activating a sign, pet feeder, vent or window control or other daily function

PROJECT 4

Measured Lever & BASIC Stamp Circuit

This project provides a sophisticated way to measure and control the operation of an Electric Piston and to cycle it at the maximum rate allowed by its surrounding conditions.

The BASIC Stamp microcomputer forms the basis of an inexpensive, flexible and easy to program system that can activate an Electric Piston based on a variety of input conditions, and can report to an external computer via an RS-232 serial port.

Construction:

Use any standard electronic assembly techniques (bread board, perf board, etc.) and build the circuit as shown. Using a 14-pin edge connector to connect to the BASIC Stamp allows it to be removed and used with other projects without requiring unsoldering.

Assemble the mechanism from plastic sheet, using screws for adjustability. You may mount the limits switches on their own panels which can be loosened and repositioned for fine adjustments to their "on" and "off" points.

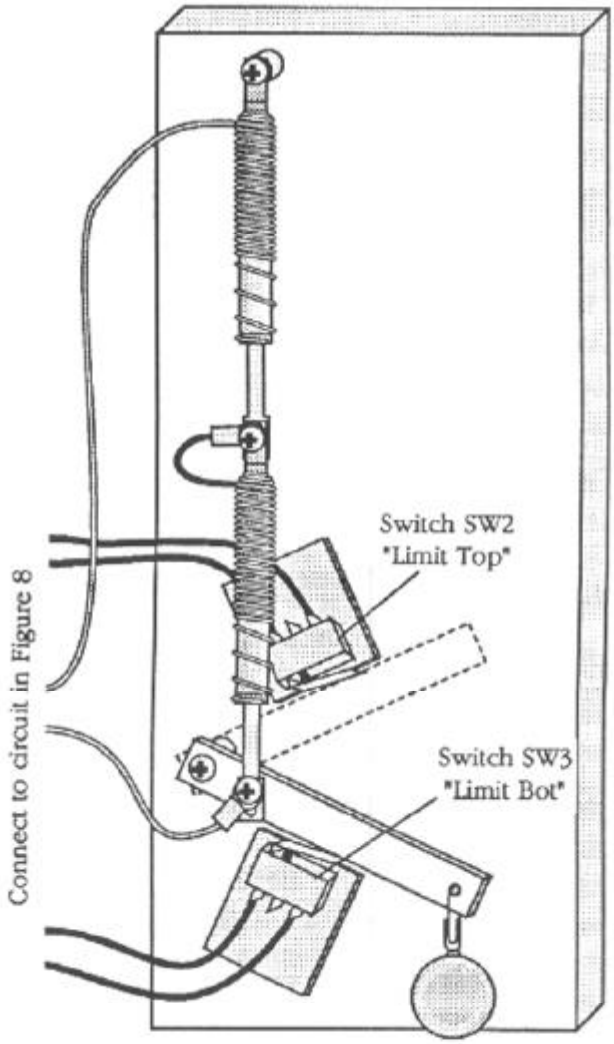


Figure 7 Project 4, Lever Mechanism with Limit Switches Two Electric Pistons connected end to end give twice the stroke distance while using the same current level and giving the same strength (450 grams). The top and bottom limit switches indicate the travel of the lever to the attached computer circuit (Figure 8), permitting full cycling of the Electric Pistons at their maximum cycle rate.

Lever Panel Parts List

2	each	Electric Piston
1	each	Base, plastic sheet, 12 x 24 x 0.4 cm
2	each	Switch base, plastic, 3 x 6 x 0.2 cm
1	each	Lever, plastic, 1 x 10 x 0.4 cm
2	each	Screw, #4-40 x 1/4"
2	each	Screw, #4-40 x 1"
2	each	Standoff, #4, 1/4"
6	each	Nut, #4-40, hex
4	each	Washer, #4, flat
2	each	Ring lug, #4 (Digi-Key #A1091)
2	each	Switch, lever (Digi-Key #SW143)
1	each	Weight, 45 gr (1.5 oz)
		Wire, insulated, 22 AWG min.

How It Works:

In this device, the BASIC Stamp activates the Electric Piston which contracts to lift a lever and hanging mass. As the lever reaches the top of its stroke, it closes a switch. The BASIC Stamp detects the switch closure and turns off the power to the Piston, which begins to cool and relax. When the Piston fully ex-

BASIC Stamp Interface Circuit Parts List

3	EP1-3	Electric Piston
1	U1	PCBA, BASIC Stamp (Parallax or Digi-Key)
3	R1,5, 6,9-11	Res, 1K Ω, 1/4 W (Brn, Blk, Red, Gold)
1	R2	Res, 22K Ω, 1/4 W (Red, Red, Org, Gold)
2	R3,4	Res, 10K Ω, 1/4 W (Brn, Blk, Org, Gold)
1	R7,8	Res, 100K Ω, 1/4 W (Brn, Blk, Yel, Gold)
1	C1	Cap, 6800 µ F, 16 V min, aluim. electrolytic
2	Q1,2	Transistor, IRFZ30, MOSFET PNP (Digi-Key #IRFZ30)
2	I1,3	LED, Red, T-1 size
1	I2	LED, Green, T-1 size
1	J1	Power Cord, 110VAC
1	J2	Connector for RS-232 (see text)
1	U1	Connector, 14 pin SIP (for Stamp Rev D)
1	SW1	Power Switch, SPST, 110VAC, 5A
1	T1	Transformer, 5V 4.8A (Digi-Key #T120)
1	BR1	Bridge Rectifier, 6 A (Digi-Key #PB61)
1	F1	Fuse, 0.5 A
		Hook up wire
		Wire wrap wire
		Perf board
		Insulated enclosure
		Mounting hardware

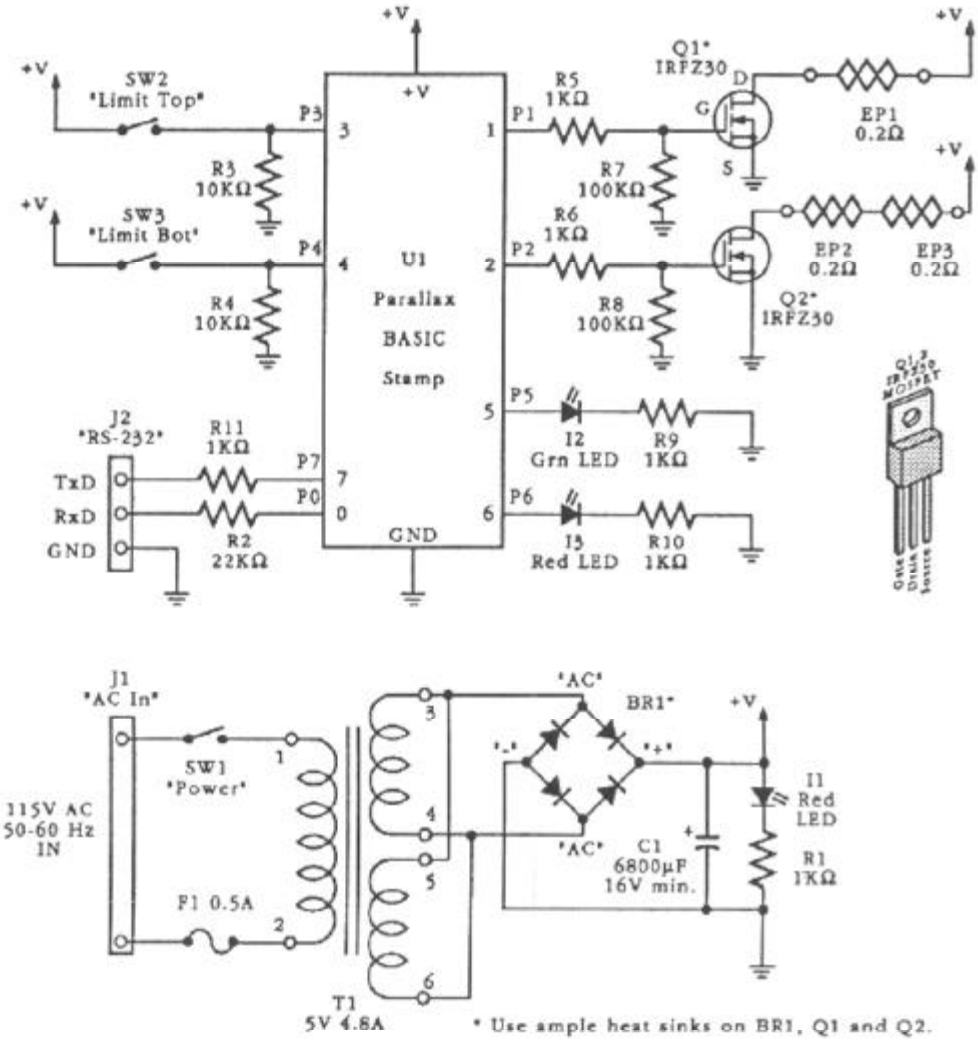


Figure 8 BASIC Stamp Interface Circuit
The BASIC Stamp microcomputer provides a flexible and economical method to control this and other projects. This circuit can be built directly on the Stamp's prototyping area, or on a separate board and attached by a 14 pin SIP header. For standard serial port connections to either Macintosh or PC type computers, see Figures 10 and 11.

tends, the lever closed the lower switch, and the BASIC Stamp reports the contract time, relax time and total cycle time (in seconds) via the RS-232 serial connection to a computer running a terminal emulation program. The Stamp then repeats the cycle.

Variations:

Log the data reported over the RS-232 serial line to develop statistics for the performance of the Electric Piston under various conditions. Try placing the whole mechanism inside a refrigerator or freezer and see how the change in surrounding temperature affects its performance.

Refer to the BASIC Stamp Programmer's Guide for more on the Stamp and its operation.

Build a circuit with additional outputs to drive

more Electric Pistons. Add position sensors to allow the Stamp to position and hold a Piston in place.

Use several Pistons connected physically and electrically in series to make a device with a longer stroke. For more strength, connect more Electric Pistons mechanically in parallel. They can be powered in series, or driven alternately by separate drive circuits.

See the *Muscle Wires Project Book* for additional projects related to electrically activated shape memory alloys, including robot hands, teleoperated devices, motorless walking machines, and tons of ideas.

Good luck and happy discovering!

```
' EPtest8.BAS - RG 9406.04
' BASIC Stamp program
' Program to cycle Electric Piston and report timing counts in seconds
' via serial port or Debug command. Uses upper and lower limit
switches
' to detect travel of Piston and lever arm.

       dirs = %11100110          'Set pin 1,2,5,6,7 as output, others
input

symbol EP1 = pin1                'Define port names
symbol EP2 = pin2
symbol LimTop = pin3
symbol LimBot = pin4
symbol GrnLED = pin5
symbol RedLED = pin6
symbol TxD = pin7
symbol RxD = pin0
symbol liftcnt = W1
symbol dropcnt = W2
symbol totlcnt = W3

Go:    liftcnt=0 : dropcnt=0     'Clear counters

Lift:  EP1=1 : EP2=1             'Turn EPs 1 and 2 on when at bottom
L2:    if LimTop=1 then Drop     'If top limit on then power off
       gosub ckled               'Check & set LEDS
       liftcnt=liftcnt+1
       goto L2

Drop:  EP1=0 : EP2=0             'Turn EPs 1 and 2 off when at top
D2:    if LimBot=1 then Report   'If bottom limit on then print results
       gosub ckled               'Check & set LEDS
       dropcnt=dropcnt+1
       goto D2

Report:liftcnt=liftcnt/241       'Adjust for seconds
       dropcnt=dropcnt/241
       totlcnt=liftcnt+dropcnt

'Send results out serial port with tabs (10) and CR (13)
       serout TxD,N300,(#liftcnt,10,#dropcnt,10,#totlcnt,10,13)

'Send results to Stamp monitor program
       debug"Times: ",#liftcnt,#dropcnt,#totlcnt,cr

       goto go                   'Start next cycle

'Subroutine to check & set LEDs
ckled: if LimTop=1 then GrnON    'If LimTop on, GrnLED on
       GrnLED=0                  'Otherwise off
       if LimBot=1 then RedON    'If LimBot on, RedLED on
       RedLED=0                  'Otherwise off
       return
GrnON: GrnLED=1                  'Turn green LED on
       return
```

Figure 9 Lever Test Program Enter this program as a BASIC file using the software provided with the Stamp Development Kit, then program the Stamp. Modify the instructions shown here to write your own software for running a variety of other Electric Piston devices.

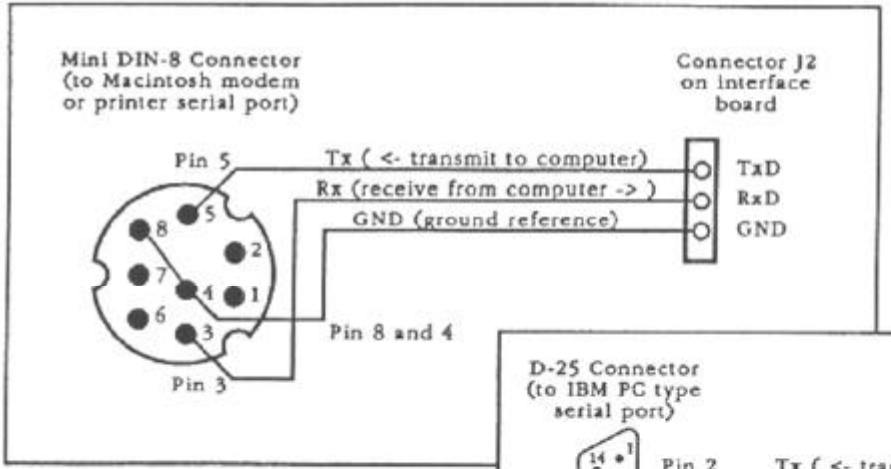


Figure 10 Serial for Macintosh Computers Obtain the correct connector size and style to match your computer. The Mini DIN-8 connectors can be obtained from electronics suppliers such as Mouser (#171-2408), or by adapting an appropriate printer or modem cable. See Figure 8 for the main part of the interface circuit.

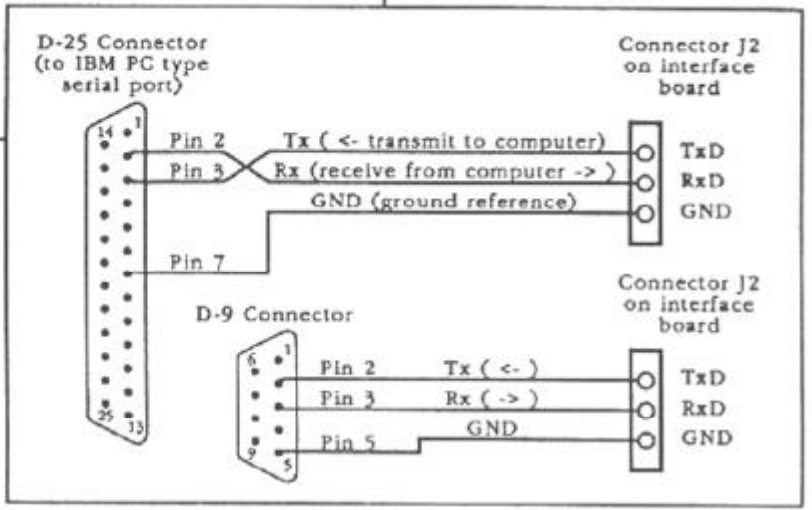


Figure 11 Serial for IBM PC-type Computers For both 25 and 9 pin ports.

Polapulse P100 Battery Specifications

Size: 9.5 cm x 7.7 cm x 0.5 cm (3.7 in. x 3 in. x 0.19 in.)
Weight: 27 grams (0.95 oz.)
Voltage: 6 volts nominal, 6.3 volts open circuit
Temperature range: minus 7°C to 54°C (20°F to 130°F)
Chemistry: Leclanche (zinc - manganese dioxide)
Discharge current (through 0.1Ω):
- 15 amps instantaneous
- 8.5 amps after 30 seconds
- 4.5 amps after 60 seconds

Internal resistance: 0.5Ω at 5 amp drain.

Not normally rechargeable. Batteries can be connected in series and/or parallel to achieve higher voltages, amperages or capacities.